

Study of Backgrounds at JLC IR ^{*}

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Abstract

A full simulation program based on GEANT4 has been developed to study beam-induced backgrounds in the JLC beam delivery system. We report some results obtained using this program.

1 JLC Beam Delivery System

The beam delivery system (BDS) of the JLC is ~ 1.4 km long and consists of four parts: switch-yard, collimator, final focus system (FFS), and beam dump as shown in Fig. 1. The BDS serves multiple purposes: (i) to switch beams from the main linac or the bypass line to the first or second interaction point (IP), (ii) to create a finite crossing angle at the IP, (iii) to collimate the beams to eliminate possible backgrounds at the detector, (iv) to focus the beams at the IP, (v) to protect the machine from damages due to beam aborts, and (vi) to dump the spent beams after collision safely. The design of the JLC BDS is based on that of NLC BDS, because of the close similarity of the overall machine design and parameters. A notable difference, however, exists between JLC and NLC in a layout of the BDS. It arises from the beam crossing angle at the first IP; JLC has a small angle of 7 mrad while NLC has 20 mrad. Figure 2 shows the geometry of a JLC BDS. The aspect ratio in this diagram is highly distorted to illustrate the bending of the beam lines and the

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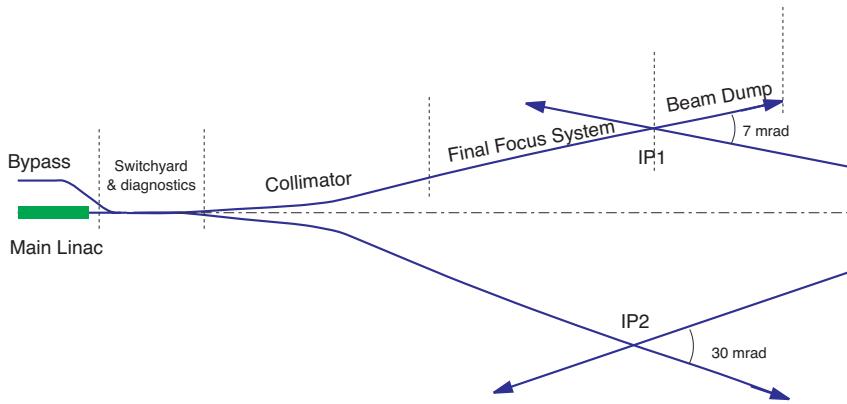


Figure 1: Schematic plan of the beam delivery section.

beam crossing angle at the IP. Figure 3 shows the optics functions in the collimator and final focus sections. In the following we assume the electron beam energy of 250 GeV.

2 BDS Simulation

A full simulation program, LCBDS [1], has been developed to simulate the entire BDS. The LCBDS uses GEANT4 [2] to model the individual beamline elements including drifts, all (dipole, quadrupole, sextupole, octupole, and decapole) magnets, collimator elements (spoiler, absorber, and energy slit), and a beampipe. Physics processes currently included in the code are multiple scattering at the beamline elements, electromagnetic shower and photon conversion to muon pairs. In order to gain reasonable statistics, we increase the muon production cross section by a factor of 100 to generate events and, then, scale down the results by the same factor. In order to verify the tracking capability of the simulation, the transportation of the core beam has been simulated from the entrance of the BDS to the IP and the results are compared with the beam profile shown in Fig. 3 obtained by using SAD program [3]. The core beam is assumed to have a size of $\sigma_x = 14.8 \mu\text{m}$ and $\sigma_y = 658 \text{ nm}$, and an angular dispersion of $\sigma_{x'} = 0.413 \mu\text{rad}$ and $\sigma_{y'} = 0.093 \mu\text{rad}$ at the entrance of the BDS. Figure 4 shows the beam size at the IP obtained by the LCBDS. The results (214.5 nm and 2.73 nm in x and y directions, respectively, in

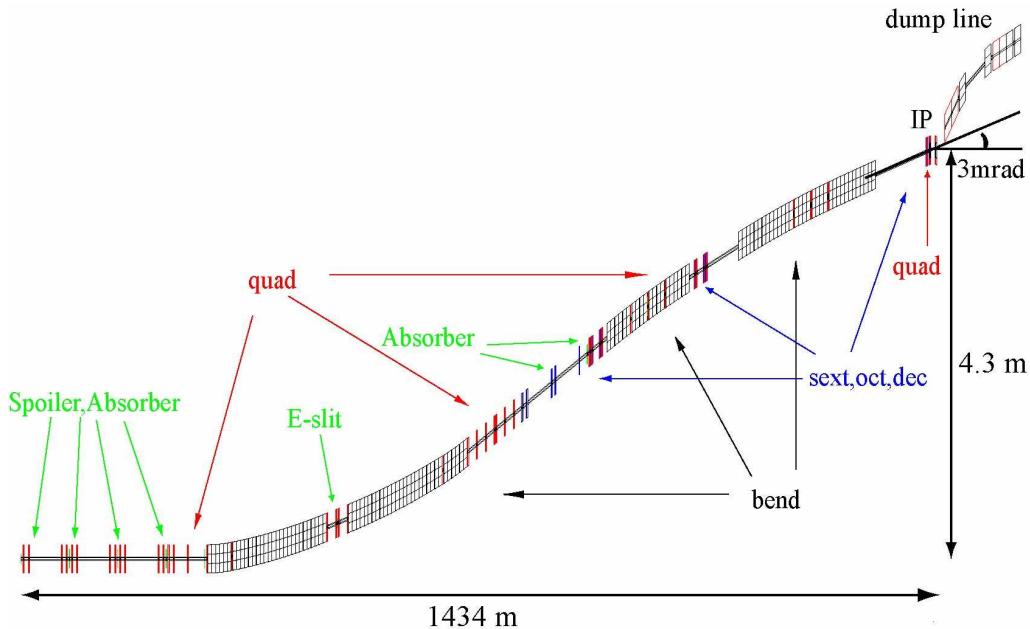


Figure 2: Geometry of JLC beam delivery system. Aspect ratio between vertical and horizontal scales is highly distorted.

rms) well reproduce the design values (211 nm and 2.7 nm).

3 Detector Backgrounds

The sources of the background can be categorized as follows:

1. Upstream background: background produced upstream of the IP. This includes synchrotron radiation generated at the final focus quadrupole and bending magnets, and muons produced in electromagnetic showers arising from lost halo electrons/positrons. Because the collimators are designed to scrape off halo particles, muons are produced predominantly at the collimators.
2. IP background: background generated at the IP. Produced via e^+e^- collisions at the IP are disrupted primary beams, beamstrahlung photons, e^+e^-

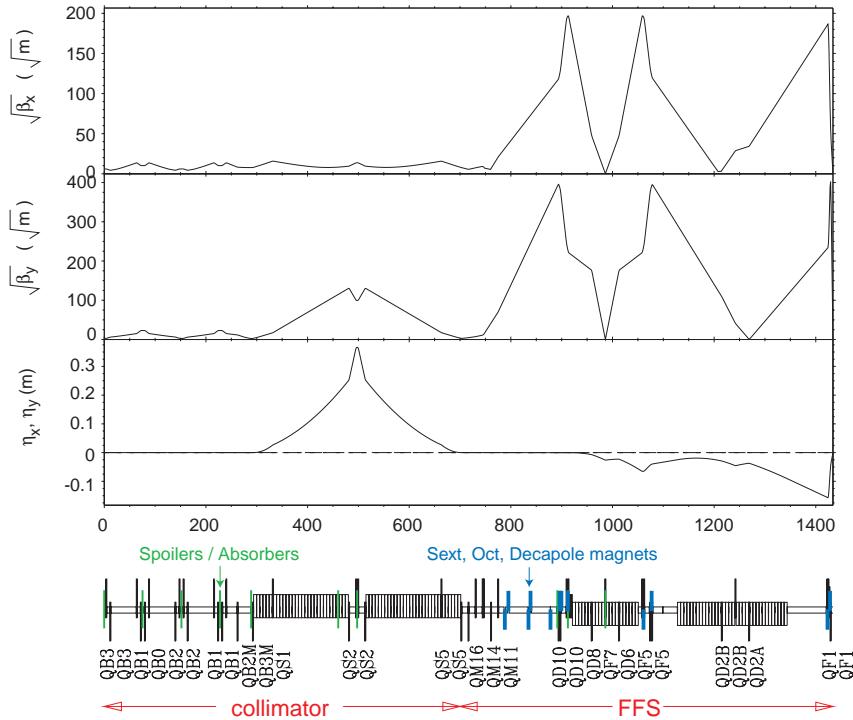


Figure 3: The optics functions of the beam delivery section.

pairs from beam-beam interactions, radiative Bhabhas and hadrons from two-photon interactions.

3. Downstream background: background produced downstream of the IP. This concerns secondary neutrons produced at the extraction line and beam dump. A large number of low-energy neutrons can drift back and back-shine the detector.

We report on-going efforts to identify background sources based on the LCBDS simulation.

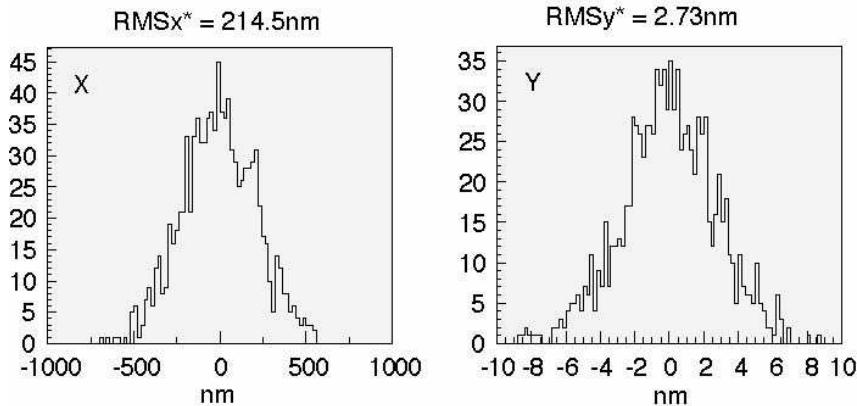


Figure 4: The beam size at the IP, obtained by the LCBDS.

3.1 Synchrotron Radiation Background

Synchrotron radiation photons reached at the IP are predominantly generated at the final quadrupole magnets. Photons generated at the bending magnets upstream of the final quadrupole magnets also reach at the IP. Figure 5 (a) shows the spatial distribution of the synchrotron radiation photons arising from a nominal beam (core beam) containing 10^5 electrons. The extent of y distribution is limited within ~ 0.5 mm. The x distribution, however, is wider and has a long tail extending to ~ 1 cm. This is due to photons generated at the bending magnets. These photons are mostly contained within the beampipe (nominally with a radius of 2 cm) even without any mask and therefore, will not be serious background to the detector. The energy distribution of the photons is shown in Fig. 6 (a). The mean photon energy is ~ 0.35 MeV.

Synchrotron radiation photons originating from the beam halo, electrons with large amplitudes, can be more spread and could become serious background. In the current design the collimator section removes halo particles with amplitudes larger than $\sim 12\sigma_x$ or $\sim 50\sigma_y$ from the beam center. The size and material of spoilers and absorbers used in our simulations are summarized in Fig. 7. In order to simulate the collimator section performance and the remaining synchrotron radiation, we generate the beam halo electrons that distribute uniformly over $50\sigma_x$ and $200\sigma_y$

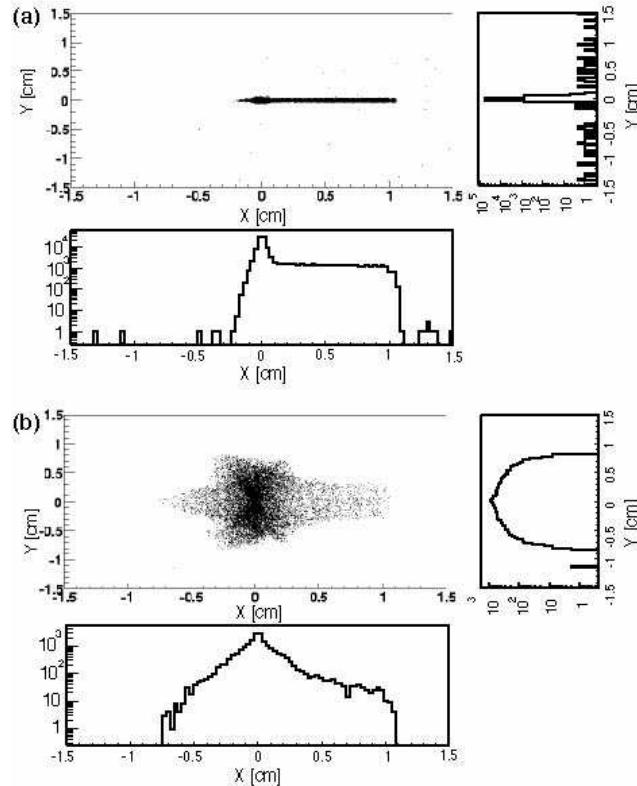


Figure 5: The spatial distributions of the synchrotron radiation photons arising from (a) a nominal beam and (b) a beam halo .

region, where σ_x and σ_y are the nominal beam size at the entrance of the BDS. The angular distribution of the halo is also uniform over $50\sigma_{x'}$ and $200\sigma_{y'}$. The spatial and energy distributions of the resulting photons (without any mask near the IP) are shown in Figs. 5 (b) and 6 (b). These photons are still contained in the beampipe and will further be reduced by a mask system.

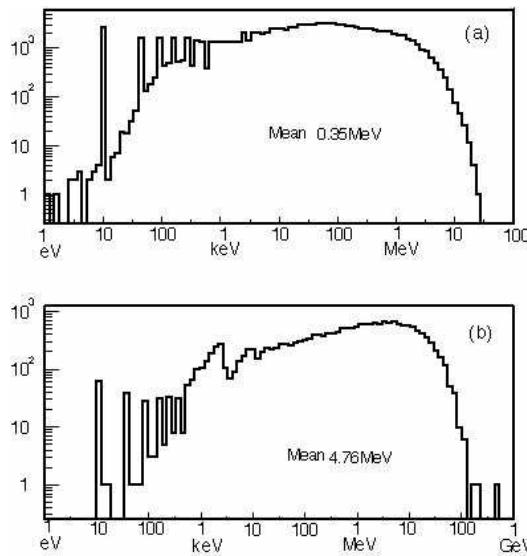


Figure 6: The energy distributions of the synchrotron radiation photons arising from (a) a nominal beam and (b) a beam halo.

3.2 Muon Background

The collimator section in turn can become a source of the background. Muon pairs can be produced via photon conversions in the electromagnetic showers created by the lost halo electrons. Figure 8 shows the energy and spatial distributions of the muons reached at the IP if the BDS is not equipped with any muon shield. The average muon energy is 61 GeV. The probability for a 250 GeV electron lost at the collimator to produce a muon at the IP (without muon shield) is estimated to be $\sim 1.4 \times 10^{-5}$. Figure 9 shows where along the BDS those muons are produced. They are produced predominantly at the collimator section. The magnetized iron pipes surrounding the beam pipe have been considered as an option of the muon shield. Its design and detailed simulation are under study.

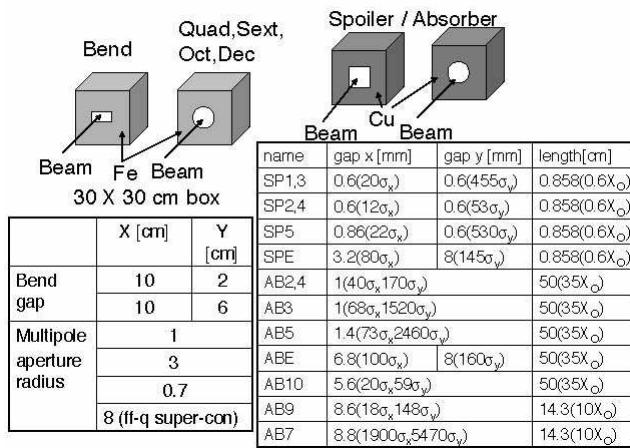


Figure 7: Summary of dimensions and material content of BDS elements.

4 Conclusion

We have presented some of the early results obtained using a beam delivery system simulation based on GEANT4. This program, LCBDS, has successfully reproduced the beam profile as designed. We have shown the results on the synchrotron radiation and muons produced in the JLC beam delivery system.

References

- [1] Linear Collider Beam Delivery System (LCBDS) simulation code, M. Iwasaki (masako@phys.s.u-tokyo.ac.jp) and K. Tanabe (tanabe@hep.phys.s.u-tokyo.ac.jp), unpublished.
- [2] <http://wwwinfo.cern.ch/asd/geant4/description.html>
- [3] SAD (Strategic Accelerator Design), K. Oide *et al.*, <http://www-acc-theory.kek.jp/Accelerator/index.html>

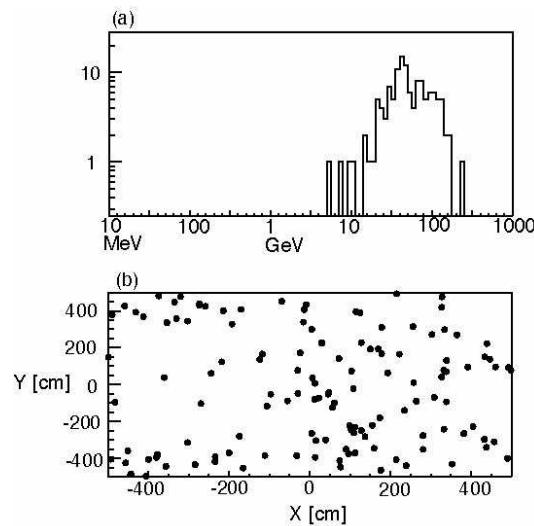


Figure 8: The energy (a) and spatial (b) distributions of the muons reached at the IP if the BDS is not equipped with any muon shield.

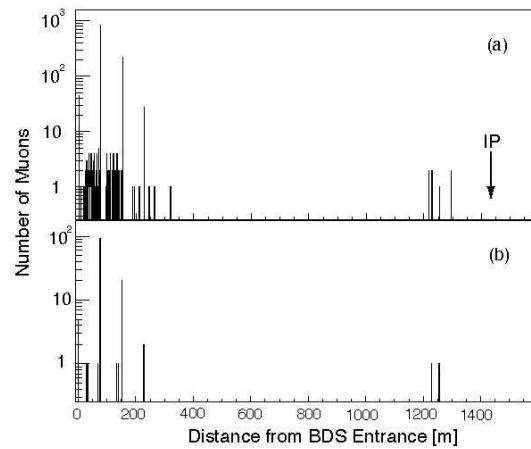


Figure 9: Production locations for (a) all muons and (b) those muons which reached the IP.